United States Patent [19]

Lynnworth et al.

[11] **4,320,659**

[45] **Mar. 23, 1982**

[54] **ULTRASONIC SYSTEM FOR MEASURING FLUID IMPEDANCE OR LIQUID LEVEL**

[75] Inventors: **Lawrence C. Lynnworth; John L. Seger,** both of Waltham; **James E. Bradshaw,** Tyngsboro, all of Mass.

[73] Assignee: **Panametrics, Inc.,** Waltham, Mass.

[21] Appl. No.: **111,466**

[22] Filed: **Jan. 11, 1980**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 881,754, Feb. 27, 1978, abandoned.

[51] **Int. Cl.**[3] **G01N 29/02**

[52] **U.S. Cl.** ..... **73/589;** 73/53; 73/290 V

[58] **Field of Search** ..... 73/53, 290 V, 589, 592, 73/597, 599, 629, 644

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,966,058	12/1960	McSkimin	73/597
3,512,400	5/1970	Lynnworth	73/597

FOREIGN PATENT DOCUMENTS

648023 9/1962 Canada .

OTHER PUBLICATIONS

J. and H. Krautkramer–*Ultrasonic Testing of Materials*, 2nd Ed., Springer–Verlag, pp. 569–572 (1977).

L. Lynnworth, "Industrial Application of Ultrasound–A Review II. Measurements, Tests and Process Control Using Low Intensity Ultrasound", IEEE Transactions on Sonics and Ultrasonics, vol. SU–22(2) pp. 71–100, Mar. 1975.

A. E. Arave, "An Ultrasonic Void Fraction Detector Using Compressional Stress Waves in a Wire Helix", Idaho Nuclear Corporation, IN–1441, Oct. 1970.

A. E. Arave, "An Ultrasonic Liquid Level Detector Using Shear Wave Attenuation in a Bar", Idaho Nuclear Corporation, IN–1442, Nov. 1970.

A. E. Arave, "Ultraso nic Liquid Level Detector Using Surface Wave Attenuation in a Tube", Aerojet Nuclear Company, ANCR–1047, Jan. 1972.

Primary Examiner—Charles A. Ruehl

Attorney, Agent, or Firm—Kenway & Jenney

[57] **ABSTRACT**

An ultrasonic system that measures either the impedance of a fluid or liquid level utilizes moderately directional, bulk SV mode sound waves generated by a transducer and propagated in a homogeneous, flaw-free solid member. The SV wave propagates in the solid along a zigzag path that reflects at a solid-fluid interface in at least two areas and at an angle of incidence that exceeds the first critical angle by at least five degrees and is less than the second critical angle by at least ten degrees. The attenuated amplitude of the wave due to acoustic coupling between the solid and the fluid measures the impedance or an impedance related parameter of the fluid. The system preferably includes a second acoustic path that serves as a reference to compensate for changes in parameters such as temperature, the nature of the fluid, the transducer, the transducer coupling, and residues or corrosion at the solid-fluid interface. In another form, the reference mechanism is a series of reflections from notches in the solid member. For liquid level measurement desensitized to variations in the liquid impedance, the solid is an elongated member that is oriented at an oblique angle, or is parallel to, the surface of the liquid. Other liquid level measurement systems utilize multiple receivers or reflectors located at the points of reflection of the zigzag wave.

54 Claims, 43 Drawing Figures